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Computational Science and Information Technology: Distance Education and Training

by

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Computational Science and Information Technology: Distance Education and Training

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1. Introduction

This report brings together some of the issues needed for training and education in the area of Computational Science and Information Technology. Curriculum, delivery, and authoring are discussed, with a focus on commercial solutions rather than the advanced Garnet and ECCE research systems described in [1] and [3].

Over the years, courses have been offered in both simulation (parallel computing) and information (Internet) technologies. These are both needed as many fields are now integrating these issues. For instance, XML-based technologies are needed to record data and assimilate it into large-scale simulations. As seen in portals, the user needs modern management technology to keep track of the increasingly complex process of computation.

There are three major on-line core courses from the past year and a half: CPS1: http://old-npac.csit.fsu.edu/projects/cps615spring00/ (computational science taught at ERDC Graduate Institute Spring 2000) and two new courses from FSU: IT1 at http://aspen.csit.fsu.edu/it1spring01/ and IT2 at http://aspen.csit.fsu.edu/it2spring01/. The last two update information technology courses that were very popular when taught from Syracuse to Jackson State from 1997-2000. They are supported by an on-line technology resource http://aspen.csit.fsu.edu/windsnow/webtech/. The IT2 course focuses in particular on XML, which is very useful in defining the interoperable datastreams and interfaces needed for multidisciplinary applications.

The curriculum used in distance education needs only to be Web-based. Currently, most experience has been with simple authoring tools such as basic HTML, exported PowerPoint, WebCT, and Blackboard. The latter two commercial systems produce visually appealing pages that typically lack rich multimedia and interactive content characteristics. Developments of standards such as SVG (XML-based standard format for 2D vector graphics) are encouraging. The best authoring products from Adobe and Macromedia should soon support this format, including a prototype Flash to SVG converter. Adobe Illustrator allows SVG output, and a PowerPoint to SVG filter is also being worked on. Such a development would allow the user to develop high-quality Web pages and export using their standards compliance to guarantee content survival during changes in vendors and products moving on Internet time. These ideas are expanded in Sec. 3.1. Looking at core courses (MPI training, base Java course above) and spending the effort to author them in a more interactive format would be beneficial. Courses whose content is still rapidly changing should probably stick with approaches such as PowerPoint, which require less investment in authoring.

ADL (http://www.adl-net.org) and IMS (http://www.imsproject.org) have produced learning object standards that address the structure of curricula above the Web page. They define a natural hierarchical arrangement as summarized in Sec. 3.3. They discuss the metadata that link pages to course modules and define prerequisites, objectives, and completion requirements. There are also standards for user-related data (administrative and grading), as well as tests and quizzes. ADL and IMS standards currently have no overlap with the authoring issues discussed above, making it worthwhile to pursue both goals – high quality authoring and standards compliant learning objects – simultaneously.

A common type of page is basic "content" surrounded by "decoration." The decoration would be advertisements or pointers to other Yahoo goodies for a Yahoo portal page. For an educational page, such as those produced by WebCT or Blackboard, the decoration is a group of buttons accessing services such as "chat room," "class resources," "send mail to instructor," WebTop Services (search etc.), and links to other content (Next, Previous, More Detail). This page structure is best thought of as a portal. The curriculum part is classified as a unit in IMS or ADL. The decorated page should not be directly stored but generated when the portal is invoked.

Delivery can be implemented using a combination of audio video conferencing and shared document collaboration systems. As it is difficult for any one system to be best in both areas, each should be looked at separately. In the first area, summarized in Sec. 3.2 and [2], the choice is between solutions at different levels of capability. At the high-end, the Access Grid from Argonne is pre-eminent, while the low-end HearMe system illustrates modern voice over IP desktop conferencing. The research system Garnet or commercial WebEx, Placeware, and Centra can be used to support shared curriculum pages. Garnet is designed to support both the advanced authoring (Macromedia flash) and management standards (IMS, ADL) discussed in Sec. 3.3 of this report. The commercial systems WebEx, Placeware, Centra, and Latitude are discussed in Section 4.

In summary, there is a strategy that supports the emerging object standards, high-quality authoring, portals, and the best delivery systems. The following information discusses some general technology and collaboration issues. Sections 3 and 4 describe the topics summarized above.

2. Collaboration and its Technology

2.1 Background References

The user can get further information from several available Web resources including a white paper produced for ARL – [11] on collaboration issues specific to this laboratory. General remarks can be found at the Web site http://aspen.csit.fsu.edu/collabtools/ and in a report written for ERDC in May 2000 [9]. The first Web site has a detailed technology review [12] and several presentations associated with tutorials given in this area.

Published papers on collaboration technology can be found at [6] and [7]. Discussions of curriculum can be found at [4], [5], and [8].

2.2 Collaboratories

A Web-based support for people to interact with one other and with other resources – computers, documents, and instruments – is planned. This was originally called a Collaboratory by Bill Wulf in a famous Science article in volume 261, 13 Aug. 1993. This must be accomplished while technology is rapidly changing, but it is uncertain which collaborative tools, scientists, and students will actually use the requirements. This report focuses on a set of successful capabilities in which some consensus exists as to what they do and how they look to users, tasks that are now typically commercialized. There are also some useful technologies and standards on which to build. In developing an academic or government program in this area, it is necessary to identify those areas where there is a potential requirement that industry will not provide (or render this solution invalid) in the next year or so. These include special features of training, HPCC, and science. Support of hand-held devices is so poorly understood that, in spite of strong commercial interest, it remains a good research area.

Since there are now some fairly good distance education systems and more general collaboration solutions, now is a reasonable time for groups to invest in learning and using some of the tools. Capability, performance, and robustness will improve, but there seems to be consensus in several areas. Time and money invested now will give groups a knowledge basis for using future systems. The original ARL white paper discussed the differences and similarities among support of training, administration, and research. Any use of collaborative systems should take this into account when choosing what to do. For instance, most commercial education systems in today's market emphasize asynchronous collaboration, while businesses, even in training, predominantly use the synchronous systems WebEx and Centra.

Since the focus is on Web-based (distance) education and training, application areas will not be discussed in detail. Important areas that will drive the collaboratory area include:

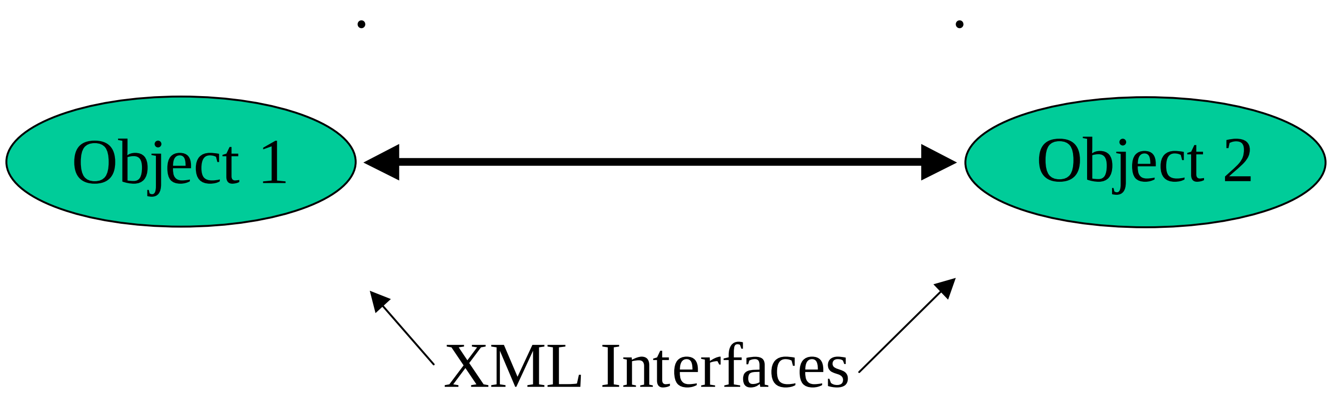
1) Distance Education including advanced seminars and training;
2) Help desks including:
   - Microsoft helping users debug problems on their home PC (connected to the Internet).
   - MSRC consulting staff interacting over distance in real-time with users who have program bugs.
   - Yahoo staff answering in-depth questions from users browsing either Yahoo's knowledge or shopping sites.
3) Scientists brainstorming difficult research issues in distributed locations.
4) Virtual communities around the world from children chatting with one another or integration of distributed organizations (such as nearly all large laboratories).
5) The members of the Indian Nation remaining in their homeland but participating electronically in modern economy ("digital.indigineousworld.org").

6) Support of HPCMO through a distributed PET team.
7) Crisis Management, Command and Control for the military.
8) For a single user, "collaboration" among different input devices. This includes a case in which a scientist controls a specialized display with a PDA controller or a wheelchair shopper accesses the mall kiosk from a hand-held keyboard.

Some key base technology trends and approaches are discussed in subsection 2.3. It is believed that the Object Web should be the basis of any modern system; typically, a user programs in Java as it has the best software engineering properties and defines interfaces and data structures in XML using a multi-tier architecture. Some important Internet trends suggest where systems will go, including the increasing bandwidth and latency of networks (Gilder's law) and the growing use of Palmtop devices [3].

2.3 Distributed Objects and Technology Trends

Any electronic artifact is by definition a distributed Object, whether it is an instrument delivering data, a computer, an on-line user, a computer program, or even the most common object – the basic Web page. As shown in the figure below, even as objects are programmed in Java, their interfaces and the object metadata will be defined in XML.

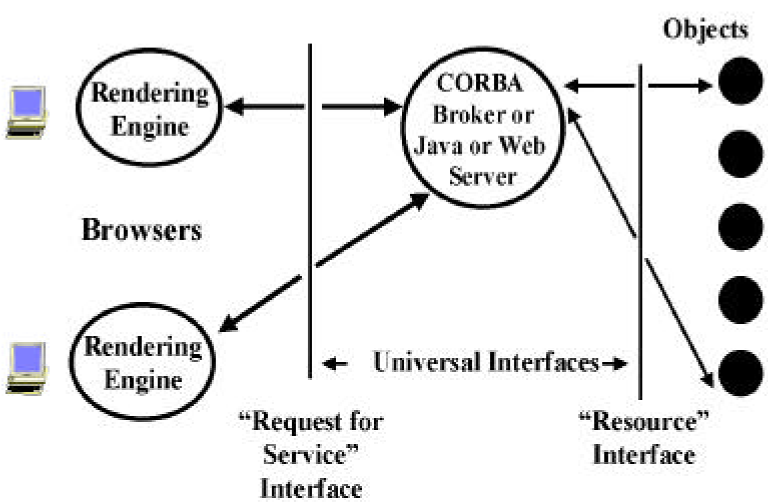


The basic approach is the same whatever the object model: COM, CORBA, Jini/RMI, SOAP(.net), or even DMSO's HLA. In each case, systems are built in multi-tier fashion so the front end rendering and back end functionality are disassociated.

Pictured below is an example of a software object being defined in XML:

```
<?xml version="1.0"?>
<!DOCTYPE application SYSTEM "ApplDescV2.dtd">
<application  id="disloc">
<target id="osprey4.npac.syr.edu">
 <status installed="Yes"/>
 <installed>
   <CmdLine command="/npac/home/webflow/GEM/JAY/dis2loc"  />
   <input>
     <inFile Path="/npac/home/webflow/GEM/JAY/" Name="disloc.output"/>
     <source Host="osprey4.npac.syr.edu" Path="/npac/home/Jigsaw/WWW/tmp"
          Name="disloc.out"/ >
   </input>
   <output>
     <outFile Path="/npac/home/webflow/GEM/JAY/" Name="simplex.input" />
     <dest Host="osprey4.npac.syr.edu"
          Path="/npac/home/webflow/GEM/JAY/simplex/" Name="s.in" />
   </output>
   <stdout Host="aga.npac.syr.edu" Path="/npac/home/haupt/webflow/history/"
          Name="job2001.out" >
   <stderr Host="aga.npac.syr.edu" Path="/tmp/" Name="haupt_job2001.err" >
 </installed>
</target>
</application>
```

As described in the earlier cited papers, collaboratories naturally combine the concepts of collaboration – or sharing objects – with portals or Web-based domain specific resources; i.e., discovering, cataloging, invoking, and rendering objects. "Collaborative portals" are therefore sometimes referred to as the natural implementation.



As shown above, a multi-tier architecture separates objects (on right) from the middle-tier where brokers and collaboration servers lie and on the left clients. Collaboration servers provide the illusion of the popular peer-to-peer architecture. Objects on one client appear to be reflected in the display of other clients. This is nearly always done through the mediation of a server. Many application areas are currently setting XML-based coarse grain object standards. One example is the work of IMS and ADL in the area of education and training (http://www.adlnet.org). These standards will not be discussed here in detail, although the tutorial Web site does have separate link (http://aspen.csit.fsu.edu/collabtools/imsadlieeejan01.html) discussing this. The issues are summarized in Section 3.3. This is definitely an important area, but the lack of agreement on how to collaborate implies that the requirements of this capability are not included in the current IMS/ADL standards. Using object technology is essential to allow powerful approaches to managing and providing services in a sustainable fashion that leverages the best available commercial infrastructure.

The continued improvement in performance and capability is important. Not only does Moore's law state that CPU performance roughly doubles every 18 months, but Gilder's law also claims that network bandwidth increases three times faster than this. Gilder, in his recent work *Telecosm* (September 2000, Free Press, ISBN: 0684809303, #184 in Amazon Sales), expresses this as the Telecosm eclipsing the Microcosm (the title of his earlier work on the CPU revolution). According to this observation, the multi-server models needed for powerful collaboration will scale, and there in fact could be a growing trend to more server side, rather than client side, computing. The network bandwidth will also support increasing multi-media content for conferencing and higher visual impact pages. This trend will enable growing use of PDAs linked to the servers with the confluence of cell phone and personal digital assistant markets propelling new capabilities. It is predicted that by 2005, 60 million Internet-ready cell phones will be sold each year and 65 percent of all broadband Internet accesses will be via non-desktop appliances. These observations motivate our interest in multi-device collaboration with PDAs and desktop clients in the same sessions [3].

2.4 Nature of Collaboration

As already mentioned, collaboration means sharing. Three classes of capability are identified:

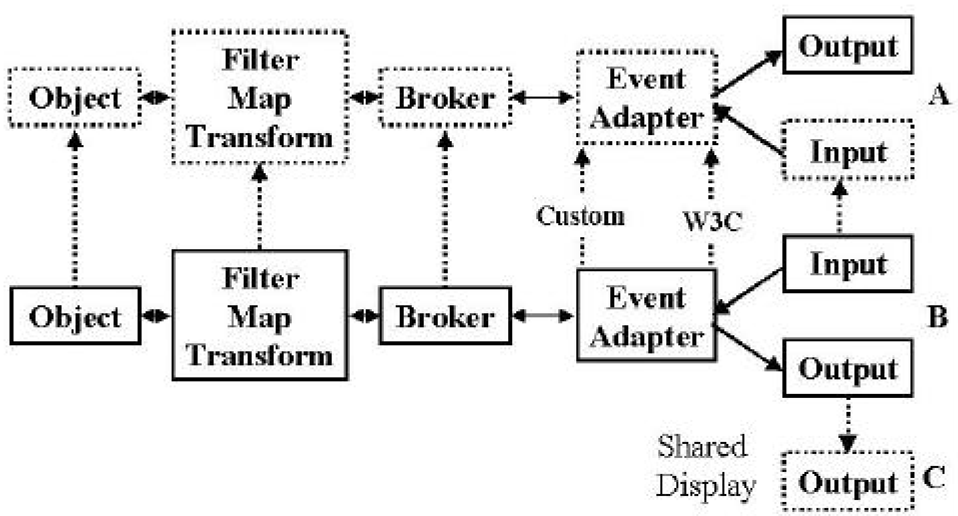
1) Share the participants: Audio/Video Conferencing
2) Basic Tools: E-mail, Instant Messenger, Bulletin Boards, White board
3) Shared resources, i.e., shared objects, which can be documents, computer programs, data streams, or visualizations. The basic tools correspond to the special case in which the shared object is a text message or simple drawing.

The objects can be shared in several ways, which trade off ease of use versus flexibility versus ease of implementation. Three object-sharing styles are discussed in this report:

1) *"True" shared event:* Actually, all these methods are shared events, but differ in the events being shared. This initial case corresponds to sharing the events defining state of object being shared.
2) *Shared display:* Events contain updates to frame buffer.
3) *Shared export:* Convert (rendering of) object to a standard form that is more flexible than bitmap of *shared display*. Build a custom sharing for this exported form. The

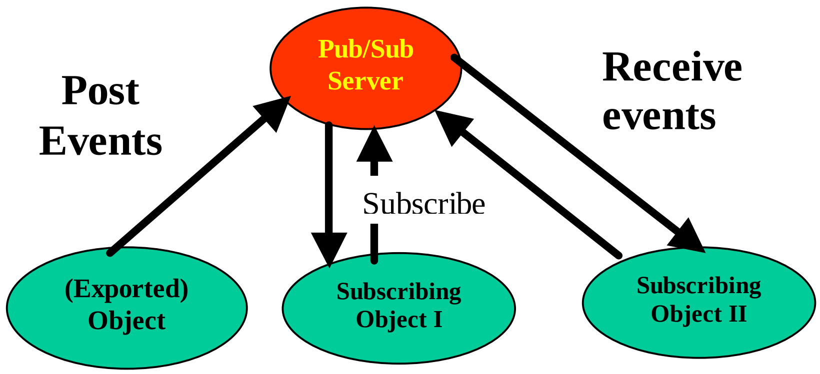
commercial WebEx system uses “a patented sharing of virtual printer” that is roughly equivalent to sharing export to PDF.

The area of collaborative visualization [10] shown below illustrates these choices:



Master user B shares with other users A and C. A visualization pipeline is formed by the computer program (object on the left above) where its output and input wend their way through multiple filters (tiers) until they are finally rendered on the particular client device that could be different for each user. As shown above by vertical arrows, an “object” can be shared at any stage in the pipeline. The simplest case (user C) is *shared display* when the final frame buffer is shared. The basic *shared event* collaboration shares the original object, perhaps replicating it but then exchanging state information. The user A has maximum flexibility to use or ignore B’s visualization state change. In particular, A has no need to use the same display device as B; B could be a high-end CAVE, A on a PDA. *Shared export* corresponds to one of the intermediate arrows where one is inside the pipeline at a stage where the format is some standard such as HTML, PDF, Java2D or 3D, or SVG (Scalable Vector Graphics). Then the user can build a generally useable collaborative viewer for this intermediate form and produce a powerful environment in a re-usable fashion. The above figure illustrates why it is difficult to build collaboration systems. Even if what needs to be done is agreed upon, i.e., in this build a shared visualization, there are many ways to do it and it can only be accomplished by building experimental systems and seeing how they are used.

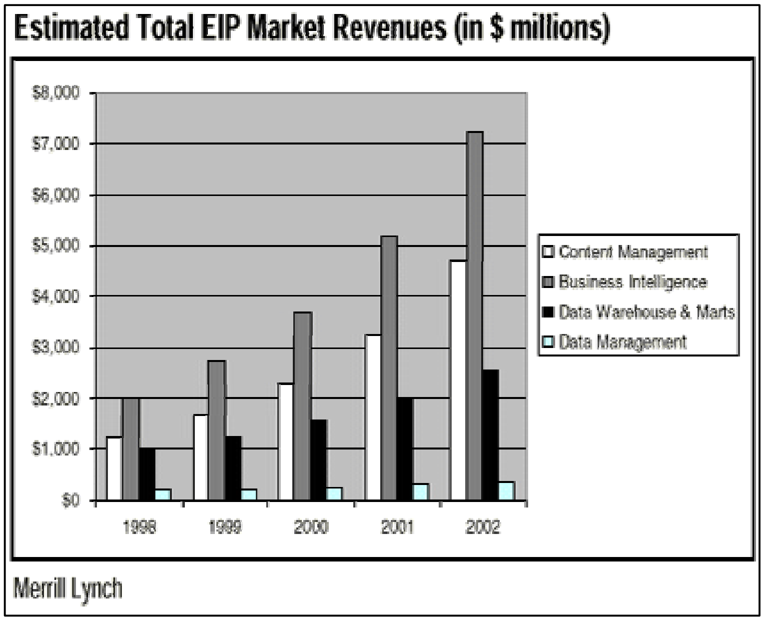
Finally, if there are many shared objects, then management capabilities are required to store, catalog, and retrieve them. This management capability needs to be linked with the collaboration system and in some applications has special requirements such as those that store grades and homework in learning systems.

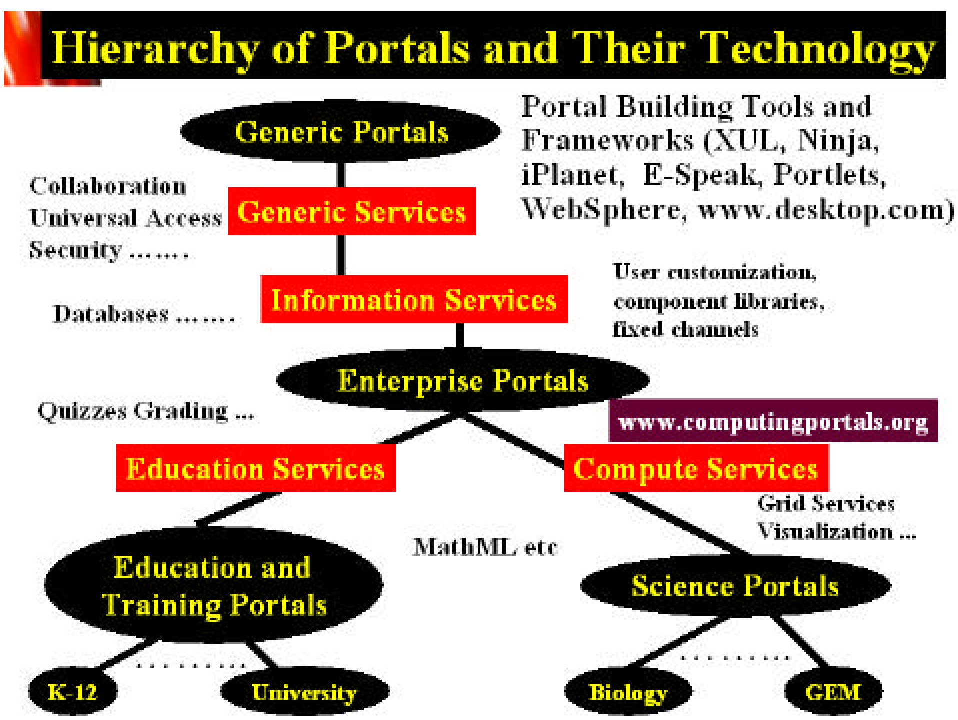


A critical distinction between synchronous (real-time) and asynchronous collaboration will now be discussed. Note that the Web is full of objects – Web pages sitting on Web servers – and these support asynchronous collaboration obtained when someone posts a Web page and later someone else looks at it in their own time. One of the attractions of Web-based collaboration is this incredibly simple yet powerful asynchronous model. Replacing a Web document by a “CGI script” or servlet (Web interface to program, database, etc.) implies that the Web supports general multi-tier object sharing. This capability, abstracted as the Publish/Subscribe mechanism shown above, is more useful with the addition of some mechanism (automatic e-mail, instant messenger, or word of mouth) to tell the collaborating client when new information is posted. Adding synchronous collaboration to this model involves providing real-time notification and automatic update for changed objects. Of course, this is not simple, reliable, or convenient.

Some important capabilities described in the long report [12] are omitted here. This review covers instant messengers – a popular component of collaboration – that is similar in function to text chat rooms. They have some special value to notify students and teachers to wake up – the class is starting. It also covers an asynchronous module of importance, namely calendars and scheduling systems. There are emerging standards in both the messengers and calendars that will enable the inoperability of these capabilities among different systems.

2.5 Collaborative Portals





Yahoo first popularized portals but they have recently been applied to Enterprise information systems, as discussed in a report by Merrill Lynch. The report forecasts a growth in this software area up to some $15 billion in 2002 as shown in the first figure of this subsection. These developments are seen as very important, as they will drive technology. Distance education is “just a collaborative portal” and information is the core of education. Thus, Enterprise technology is expected to impact education. This already is evident with database and Lotus Notes being used in several important education portals. To a lesser extent, computing portals are also impacted by these pervasive developments; in this case, there are more domain dependent objects and therefore less overlap.

As shown above, computing and education portals will be built on top of infrastructure designed for commodity and information portals. As these commercial activities are still rapidly developing, the user must expect a significant amount of experimentation until consensus best practice emerges. Until industry gets it right, what goes on must be carefully monitored and adjusted as needed.

3. Distance Education and Training

3.1 Authoring Models for Web Pages

How collaborative services depend on the nature of the object being shared has already been discussed. For a shared Web page, the object is authored in some fashion or another. This can be Word, PowerPoint, a native HTML editor, or a high-end, possibly multimedia page produced with Macromedia or Adobe tools. Sophisticated Web pages are expected to grow in importance, especially in areas such as education where collaboration technology can increase competition and the potential audience. Market pressures will demand that providers provide the best possible learning environments. In the long report [12], Macromedia technologies, in which Flash and Shockwave are perhaps the most popular high-end authoring systems, are reviewed. The current tools are not well tuned for education, in which the user needs to make a lot of similar pages that can be easily updated to take account of changing curricula in rapidly evolving fields such as computer science. The situation is expected to improve as powerful XML-based systems using XSLT style sheets become available. It is interesting to not that Macromedia has acquired Allaire and its leading database driven template system, Cold Fusion.

Authoring style is important for collaboration systems, as good sharing is more difficult for the more complex Web pages produced using Flash and similar technologies. For instance, a user needs not just to share the page but also the interactive controls. Here, there are several important developments in the Web Consortium W3C standards community (http://www.w3c.org). The W3C Document Object Model, or DOM, defines precisely the object structure of W3C-compliant Web pages. The DOM definition is only just being completed, with the key (for collaboration) event characteristics emerging in the level 2 and 3 W3C DOM specifications. This should alleviate the well-known difficulties coming from the very different DOM implementations in Microsoft and Netscape browsers. Unfortunately, no browsers currently support the latest standards, and with an 87 percent market share, Internet Explorer is not actively tracking these changes. The Netscape 6 browser was recently released, but it still too immature for serious work. Although it does have excellent W3C standards compliance, even here it only supports level 1 of the DOM at this stage. The possible importance of SVG – the W3C Scalable two-dimensional Vector Graphics standard – is stressed. All Adobe products of relevance can export to SVG, and this company has a free SVG viewer as a plugin to Netscape and Microsoft browsers. Flash has an open format with a prototype SVG converter available from the University of Nottingham. PowerPoint can also be converted to this syntax, although the current Office 2000 exports to VML – Vector Markup Language that was a precursor to SVG. This conversion is being worked on, but a user can, with less efficiency, produce SVG export from PowerPoint by going through Windows metafiles and Adobe Illustrator as intermediate forms.

SVG is important for any 2D visualization and scientific whiteboards. SVG is being used for the whiteboard available with the Gateway portal [13]. Both the authoring and visualization community should study SVG, which could be very important for interoperability.

There are several other important standards that affect authoring: MathML is the new standard for mathematics; SMIL is a complete syntax for incorporating multimedia into Web pages; OpenOffice (http://www.openoffice.org) is Sun's effort (through its StarOffice product) to define standards for productivity tools; and WML is potentially important for content aimed at wireless devices. The W3C also has a major effort in universal access that should be tracked. After a transition period, many important developments will eventually enable sophisticated pages to be manipulated and shared in standard fashion. Now is a reasonable time to explore use of technologies such as Flash. As it is clear how they will escape their current proprietary base, investment in such material will have a long-term future.

3.2 Audio-Video Conferencing

In using Tango for distance training, audio-video conferencing was always problematical and the area most likely to lower the quality of the session. The essential problem is audio for this requires negligible bandwidth (a few kilobits per second), but high quality of service as the human ear is very sensitive to audio distortion. The current Internet does not support quality of service – the user must "buy it" with bandwidth and hope that the packets get through. In the case of video, there is less of a problem. Although the bandwidth needed is higher than for audio, the eye is much more forgiving of broken images, especially if these are "just postage stamp talking heads." Quality of service is less critical for video. Remember that curricula material is transmitted separately from the multi-media and this will always be high quality.

The HearMe approach to desktop audio is described in detail in [2]. This is a low-end solution that enables an arbitrary mix of conventional phones and Internet audio streams to participate in a conference. All sources are digitized for later replay. It is ironic that conventional telephones have both quality of service and handsets with echo cancellation and tend to outperform Internet solutions. This audio supports the G.723 (modem) and higher quality G.711 standard codecs. Ref. [2] also describes the radically different approach of Argonne/NCSA's Access-Grid technology aimed at large rooms linked by high-quality networks. This system supports multiple high-quality audio and video streams and each client needs 20 megabits per second network bandwidth. The premier high-end system is aimed at a rather different model than HearMe; the Access Grid supports interacting communities, whereas HearMe is aimed at the classic collaborating desktop scenario.

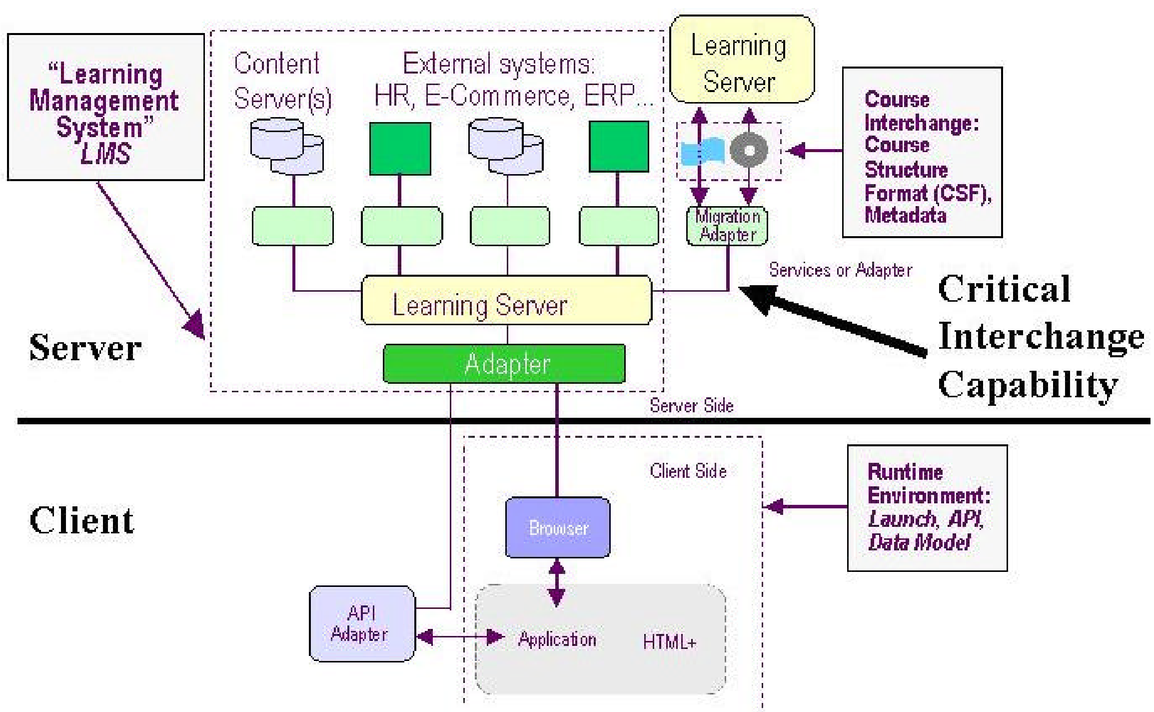
In the desktop case, the value of postage stamp video is not clear. The much richer Access Grid video has clear value but is only possible on high-speed networks and with significant technical support. Available desktop video solutions need to be reviewed.

Multi-media codecs used in conferencing are different from those optimized for Webcasts and streaming multi-media. The latter need not support interactive exchanges and can use much larger client side buffers (several seconds) with corresponding improved fault tolerance. A converter is being built to translate the archived "voice objects" in HearMe from G.711/723 to RealAudio format for better playback. One important issue is interoperability, and two important standards, H.323 and SIP, are described in [2]. Currently, the Access Grid does not support these standards, which is a weakness. There are, however, ad-hoc methods to tie non-Access Grid (AG) clients into an AG session.

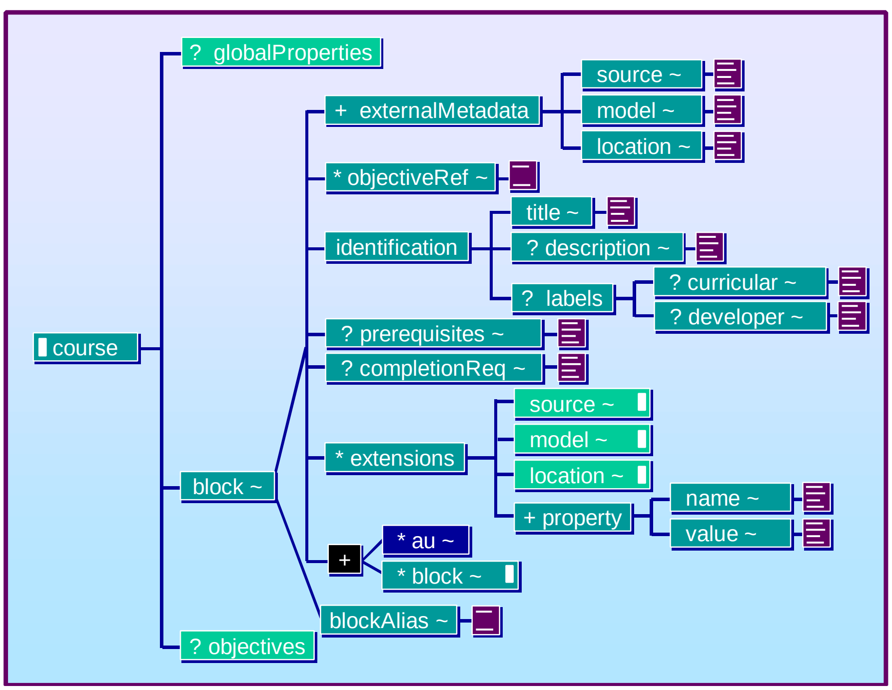
FSU, ERDC, and Jackson State AG deployment could be tested by delivery of distance classes or training sessions.

3.3 Learning Objects and their Management

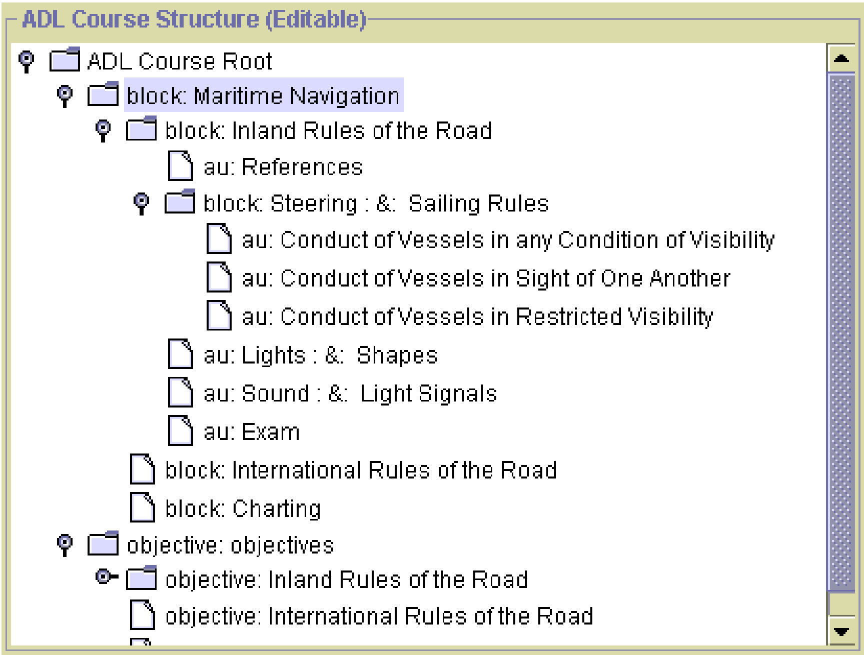
Learning Management Systems are designed to act as document repositories and provide other services such as support of student registration, quizzes, glossaries, group e-mail, homework submission, and grading. A typical architecture is shown below.



The client server interface is used to define "learning object" standards by IMS (http://www.imsproject.org) and ADL(http://www.adlnet.org) in the educational and DoD training communities, respectively. Interestingly, these efforts use the dated client server model rather than the modern multi-tier architecture adopted in state-of-the-art systems. Nevertheless, these standards are important as they identify key features of learning objects, even as more experience is needed before sustainable standards can be agreed upon. The era of distributed and distance learning is just beginning, and substantial experimentation must be expected before approaches are agreed upon and standards emerge. The picture below shows a fragment of the DoD SCORM standard for course material. Highlights include a recursive hierarchy (defined by the *block* and leaf *au* attributes) and education specific attributes including prerequisites, completion requirements, and course objectives. This diagram shows a typical display of an object structure produced by modern XML tools. The recent introduction of XML Schema will greatly help this type of work, as it is a much more powerful object specification methodology than the previous DTD syntax. Following the general SCORM learning object structure is a sample given by ADL of a military training example. These standards go down to the "Web page" as the basic unit, providing specification that can help decide what material to share but not addressing the nature of the sharing. The W3C DOM can take over and be used to define the collaboration of Web pages and their internal document fragments. Object standards are considered critical for collaboration, as the user can only effectively share information if there is enough metadata to specify its access and internal structure.



The current standards include metadata originally developed by IEEE that are aimed at defining the properties of educational objects thought of as “documents” (author, title, etc.). Additional packaging standards on how to form lectures, modules, courses, degrees, etc. from the basic curricula units are shown.



IMS has a major effort to define tests and quizzes, but it seems this may be too much detail in an area still being developed. For instance, the clever CAPA system for personalized questions (http://capa4.lite.msu.edu/capa-bin/class.html) is not currently supported. Nevertheless, the issues raised in these test and quiz standards will always be important and used in future work. IMS also includes enterprise properties, such as standards for personal information, which must be important.

Given their limitations in terms of authoring model and collaboration capabilities, it is interesting that WebCT and Blackboard are popular with educational institutions. One reason is that they provide a model suitable for the less experienced user with limited online authoring skills. It is doubtful this can be a long-term rationale, as there will be growing pressure for the highest quality learning environments and more emphasis on high-end authoring. In many areas, the user needs laboratories, perhaps in physics but – more relevantly for DoD computer science needs – programming laboratories. In distance classes with Jackson State, the rather old Virtual Programming Laboratory VPL (http://old-npac.csit.fsu.edu/projects/VPL/vpl-publications.html) was quite effective. This area deserves more attention.

One concern with systems such as WebCT and Blackboard is the realism of their goal of providing a “complete solution.” With rapidly changing technology and requirements as users experiment with new systems, a modular approach could be more sustainable. For instance, Balsoy and Sen (http://aspen.csit.fsu.edu/collabtools/senthesisdraft.html) produced an effective system to support registration, grading, and homework submission.

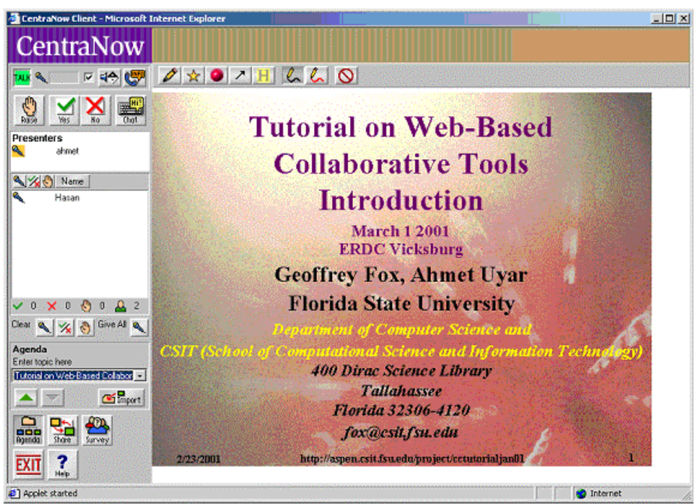
4. Commercial Web Conferencing Tools

4.1 Introduction

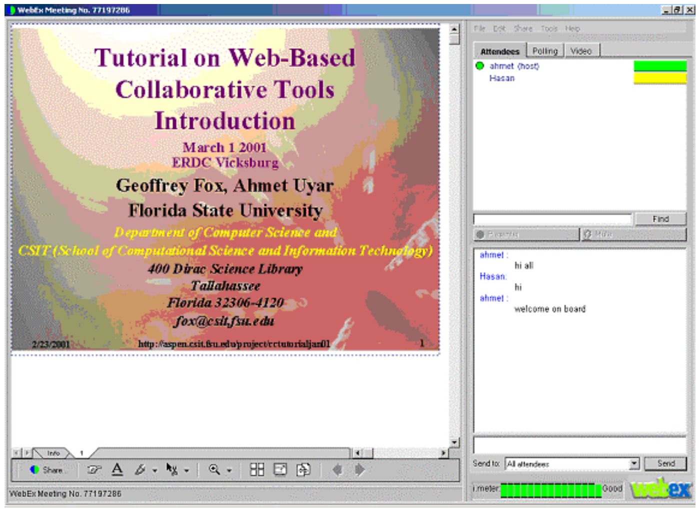
The most successful commercial conferencing companies support synchronous collaboration. Applications include education, training, seminars, and intracompany discussions such as briefing the sales force with a new product. These are the structured scenarios determined to be successful with Tango interactive. The commercial tools support very similar capabilities in each application. Typically, a presenter can do a PowerPoint slide show, ask some questions through an on-line chat and get the answers from the audience, annotate on the slides, write and draw pictures on a blackboard, and demonstrate an application during a virtual meeting. Audience members can either ask questions by talking – with permission – or through the chat. The voice is transmitted either through Internet or using teleconferencing. Some conferencing tools also provide video streaming.

There are several Web conferencing tools on the market today with varying capabilities. Ref. [12] includes an evaluation and summary of some of the most important ones. The pictures below show the rather similar interfaces that have evolved in the leading systems: Centra, WebEx, and Placeware.

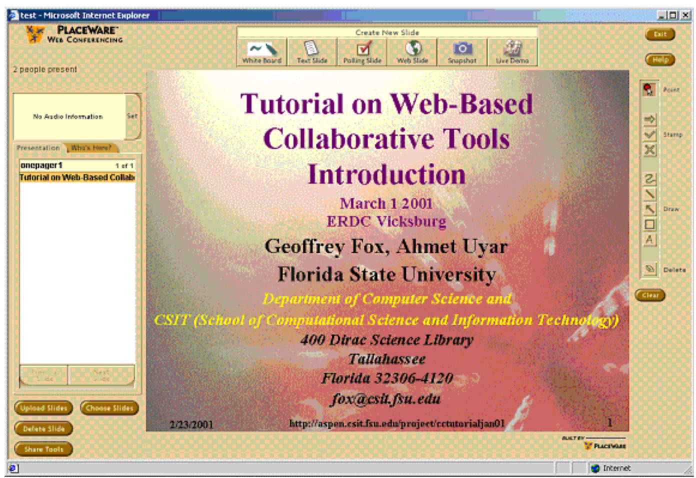
Centra:



WebEx:



Placeware:



Synchronous Virtual Environments offered by WebEx, Centra, Placeware, Latitude, and NetMeeting feature shared display and shared export (for PowerPoint). These systems have limited but nontrivial functionality in the areas of archiving, export models, management, and PDA support. In the survey of Sec. 4.2, some of the capabilities have not been examined deeply – sometimes because they were not available in the “free version” used. VNC offers a public domain shared display capability described in Ref. [12]. VNC was designed for a “different problem” – a systems czar doing administration on multiple remote machines, i.e., the master computer viewing display of a (single) client. It has not been optimized for one master display being shared with many clients as needed in distance training. Customer help desk support (including remote consulting for the MSRCs) needs the first model in which the master computer views the client display. Further, this case typically has a few session members, perhaps just two. Such help desk applications are an important business area for some of the commercial products, including WebEx and http://www.expertcity.com/

In both shared export and shared display capabilities of the reviewed systems, there is built-in support for annotation. Note the importance here of sharing objects with scalable displays. This allows the user to place the annotation in the correct location on each client display whether or not they are each viewing at the same magnification. PDF and SVG are scalable in this sense as is a fixed format such as a shared frame-buffer or a GIF/JPEG export. HTML is not scalable, as different browsers can lay out the same page in different ways that do not preserve relative positioning. All systems have some sort of chat and whiteboard tools and Audio/Video conferencing. Centra has a built-in Windows audio with a Java front end. WebEx currently uses a product from Lipstream, which has similar structure to the HearMe system described in Section 3.2.

4.2 Summary Comparison of WebEx, Centra, PlaceWare, and Latitude

	WebEx	Centra	PlaceWare	Latitude
Web site	http://www.webex.com	http://www.centra.com	http://www.placeware.com	http://www.latitude.com
Access	Browser	Browser	Browser	Browser
Shared Export	Any printable document can be shared. Anyone can zoom in or out. Uses vector-based image format. Anyone can annotate (no pointer problems).	Only PowerPoint slides supported. No resizing or zooming. PPT slides converted to gif images. Anyone can annotate.	Only PowerPoint slides supported. No resizing or zooming. PPT slides converted to gif images. Anyone can annotate.	PowerPoint, Excel, Word
Shared Display	Any application or entire desktop can be shared. Anyone can share applications with permission. Annotation is possible (only drawing curves, no texts or geometric shapes) Remote control is supported. The quality is fair. The performance is best.	Any application or entire desktop can be shared. Presenter or co-presenters can share applications. Shared application can be any size. No annotation. No remote control. The quality is good. The performance is fair.	A selected rectangular area on the desktop is broadcast to clients. Anyone can do shared display given the permission. No annotation. No remote control. The quality is good. The performance is fair.	Y but client software required.
Shared Web Browsers	No.	No.	Limited support. It does not provide a synchronized Web tour, nor does it pass the events such as page down or up. Only points the browsers to a common URL initially.	Not evaluated.
Annotation tools	Y	Y	Y	Y

Textual chat	Y	Y	Y	*
Whiteboard	Y	Y	Y	*
Polling/Voting	Y	Y	Y	N/A
Q&A (1:1 chat from student to presenter)	N	N	Y	N/A
Audio	Uses either phone or third party audio such as Lipstream.	**Built-in Audio** Half Duplex (CentraNow) Full Duplex (CentraOne and Symposium)	No audio except phone.	N
Video	Y (presenters only)	Y	N	N
Automatic notification of schedule	Y	N	N	Y (via fax or e-mail)
Recording of sessions	WebEx Recording and Playback enables recording and playback of live sessions. All annotations, shared display, and whiteboard discussions are recorded and replayed during the playback.	Centra Recorder™ lets users record live sessions and Centra Producer™ lets users edit recordings frame-by-frame. These were not tested.	Voice played back using either Real Player or Windows Media Player, and content is shown on the browser as gif images synchronously. Gif images are static and no movement is played back.	Y
Client requirements	Java-enabled browser. Automatic installation of client when accessed for the first time.	Java-enabled browser for Centra Conference. Separate client for Centra Symposium.	Java-enabled browser.	(The MeetingPlace Data Conference Option) One of the following T.120 applications (for hosts only): NetMeeting, SunForum, HP Visualize, SGImeeting. Java-enabled Web browser (Internet Explorer, Netscape Navigator) to load MeetingPlace WebShare.
Platforms	Windows; Mac (with limited functionality);	Windows	Windows; Solaris; Mac (officially not supported; no	Windows

	JAVA		audio)	
Plug-In	Y	Y	N	No client software needed but available.
Free version	Yes (up to four participants. Application sharing limited to 10 min.)	Y (up to five participants)	Yes (up to 25 participants for 15 days)	N

*Integration with standards-based T.120 applications, such as Microsoft NetMeeting, lets users share and collaborate on documents, whiteboard, and chat.

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